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ECOBAM LIVEBOX BIOASSAY STUDY

by

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INTRODUCTION

Water quality problems and particularly toxic conditions have existed in the East Waterway of Everett Harbor for a number of years. In part, these conditions have been the result of settleable solids discharged by Scott Paper Company and Weyerhaeuser Company. Accumulations of these organic solids or sludge beds, undergo anaerobic decomposition. Products of this decomposition, including hydrogen sulfide gas (H_2S) have accumulated within the sludge to a point that under reduced water pressure (low tide), the sludge breaks up, releasing trapped toxic H_2S and other decomposition products into the overlying water. Fish kills would often occur (U.S. Dept. of the Interior, 1967). Since the 1970s, a series of reductions in wastewater loads by the two paper companies have taken place in response to regulatory orders issued by the Washington State Department of Ecology (WDOE) and Environmental Protection Agency (EPA).

The *in situ* bioassay studies described in this report were carried out as part of the Ecological Baseline and Monitoring Project (ECOBAM). The intent of ECOBAM was to measure changes in water quality and biological populations resulting from load reductions at the two pulp mills which discharge to the harbor. The purpose of the bioassays was to assess water quality based on the survival of juvenile salmon during low tide in areas of the waterway affected by sludge beds (H_2S generation) and industrial wastewater discharges. It was intended that these data would provide an indication of the ability of the waterway to maintain populations of juvenile salmon, and by inference, other organisms.

HYDROGEN SULFIDE TOXICITY

Hydrogen sulfide (H_2S) is a principal toxicant addressed by this study because, for a number of years, it has been known to cause water quality problems in Port Gardner. For this reason and the fact that hydrogen sulfide and its effect on aquatic life are referred to often in this text, a description of its toxicity and physical properties follows.

Hydrogen sulfide is an anaerobic degradation product of organic sulfur compounds and inorganic sulfates. It is a highly poisonous compound with the characteristic odor of rotten eggs. Sulfur and its derivitives are found in industrial wastes including those from certain types of pulping processes. Under certain reducing conditions in the environment, these compounds can be changed to H_2S. Other sources of hydrogen sulfide are anaerobic decomposition of sewage, sludge beds, algae, and other naturally deposited organic materials. When the soluble sulfides come into contact with water, they react with hydrogen ions (H^+) to form H_2S and HS^- according to the following reactions:

$$H_2S \rightleftarrows HS^- + H^+ \text{ and } HS^- \rightleftarrows S^= + H^+$$

The reaction produces H_2S based on the availability of hydrogen ions (H^+) which is pH dependent. At a pH of 9, about 99 percent of the sulfide is in the HS^- form; at a pH of 7, the sulfide is equally divided between HS^- and H_2S; and at a pH of 5, 99 percent of the sulfide is present as H_2S, the non-dissociated toxic form (NAS, 1974).

Hydrogen sulfide toxicity is also dependent on ambient temperature and dissolved oxygen. Studies have shown that aquatic organisms are more tolerant of H_2S at lower temperatures; however, during winter months when pH tends to be lower and oxygen levels are low, the toxic effect of H_2S is increased (EPA, 1976).

Toxic levels of H_2S for aquatic organisms for long-term (chronic) exposure has been shown to be about 2.0 µg/L. Short-term (acute) exposure levels will vary with fish species, source of fish, and temperature of water (EPA, 1976). Holland *et al.*, (1960) reported that 1.0 mg/L sulfide caused 100 percent mortality in 72 hours with Pacific salmon (EPA, 1976).

METHODS

A description of the 1981 survey methods follows. These methods are basically the same as those employed during the previous years. Some adjustments have been made as would be expected for a study of this length. All tables and figures referred to in this and following sections of this report are found in Appendix I immediately following the completed text.

Site Selection

The study areas were the same as those used by the earlier investigators. Liveboxes were placed in areas where toxic conditions were most likely to occur (Moore, 1976), such as adjacent to wastewater outfalls,

sludge beds, and other points of potential toxicity. One "control" site (Area #6) was established at a point away from the toxic sources. Refer to Figure 1 and Table 1 for geographic location and test area selection criteria.

Anticipated hydrogen sulfide generation was a key factor in selecting the study sites and time of sampling. Various field observations suggest H_2S produced in the sediments by anaerobic bacteria is released during extreme low tides due to reduced pressure on the sediments (EPA, 1976). A previous study conducted in the Everett Harbor demonstrated an association between tide height, H_2S concentration, and test fish mortality (U.S. Dept. of Interior, 1967). The investigators found that mortalities were associated with detectable, but low, concentrations of sulfides occurring at or about low tide when reduced water depth allowed surface waters to be affected by toxic H_2S released from bottom sludge. As a result of the earlier studies, the ECOBAM Fish Toxicity Study was conducted during minus low tide stages (lower low water). Toxic conditions related, directly or indirectly to industrial operations, were also expected to be greatest during this tide stage due to lack of tidally induced water circulation and reduced dilution.

It should be mentioned that this study pertains to episode testing for fish mortality from various toxic elements found in Everett Harbor. Hydrogen sulfide presence and the occurrence of an episode may have appeared imminent on several occasions. Sludge compactness, tide stage, time since last gas release, and present volume and pressure of gas were considered in determining if a toxic gas release episode would occur.

Livebox stations within the study areas were periodically moved, added, or deleted in an effort to pinpoint toxicant sources and best delineate

the area affected (Anderson, D., 1981, personal communication). As an example, station locations within Area #4 underwent considerable change during the eight-year study. Initially the size and importance of this area's wastewater discharge demanded the deployment of several livebox. To fully assess the effect of this large discharge, a different configuration of livebox stations was used each year. Gradually, it became apparent that fish mortality was low in the small embayment just south of the Scott Paper Company pier and higher along the length of Scott pier where outfall 003, the Scott main diffuser, is located (Figure 2). In some cases, livebox stations were also moved as a result of waterfront changes brought about by new construction (Area #2, Area #3).

With the exception of 1979 and 1980, the bioassay studies were conducted from 1974 to 1981. The earlier investigators concluded that the four years of data collected from 1974 through 1978 had not demonstrated any change in the percent survival of test organisms. Therefore, continued testing on a yearly basis was not warranted (Anderson, D., 1981, personal communication). However, a final bioassay study was conducted in the spring of 1981 to determine if any changes in survival had taken place since 1978. All test areas, excluding Area #3 which was filled in, were assessed for this final study. Due to time limitations, only one livebox site was secured within each area of study. Sites were selected to correspond to locations used in previous studies whenever possible (Figure 1).

Test Organisms

Juvenile salmon were selected as the preferred species for the *in situ* bioassays for several reasons including: (1) natural occurrence in the study area; (2) sensitivity to changes in water quality; and (3) relative ease of capture.

Four species of salmon are found in Everett Harbor as juveniles, including chum salmon (*Oncorhynchus keta*), pink salmon (*O. gorbuscha*), chinook salmon (*O. tshawytscha*), and coho salmon (*O. kisutch*). During the study, only pink and chum fry were used as test organisms either independently or in mixed groups. Both species exhibit a strong sensitivity to H_2S and a tendency to gather in areas known to produce H_2S (Pine and Moore, 1982, personal communication). Use of either species was based on availability. In 1981 only juvenile chum salmon were used in the bioassays.

Collection and Acclimation of Test Organisms

Between April and July, schools of juvenile salmon migrating seaward from the Snohomish and Skagit river systems frequent the nearshore waters of Everett Harbor and vicinity. The schools are present in many parts of the harbor.

Collection of test organisms was accomplished with dip nets and a 280-foot bag seine. Collection was done by boat in protected areas within the East Waterway wherever salmon were visible feeding at the surface. Generally, the lengths of the pink and chum fry ranged from 3.5 to 7.0

cm.

After collection, the test fish were immediately transported to a holding pen (Figure 3) located on the west side of the waterway away from any known toxic source. The fingerlings were held at least 48 hours for acclimation. After acclimation, the salmon were carefully and rapidly transported to the livebox sites in a clean, plastic, 50-gallon container half filled with control site water. Ten specimens were selected for each test. Fish displaying aberrant swimming behavior or body and fin damage were discarded. Transfer was accomplished with a minimum of movement and agitation to limit stress on the test fish prior to the bioassay.

Livebox 6 served as a control and was deployed last to provide a measure of mortalities from the transfer process. These fish were held the longest in the transfer container (45 minutes) and would have received the greatest amount of stress. The final livebox was deployed about one hour prior to low water slack tide. Livebox observations and collection of water quality data at each station commenced one hour after deployment. Bioassay tests at the individual stations were generally terminated when either 100 percent mortality occurred or 24 hours had elapsed.

Water Quality Sampling

Water quality data included field measurements and laboratory analyses for several parameters. Table 3 lists the parameters, methods used, rationale for sampling, and applicable WDOE water quality standards.

Only one livebox station within each area, usually station "A" which was suspected to be the most toxic site, was sampled for water quality data

on a routine basis (Moore, 1982, personal communication). Sampling occurred every 15 minutes and as conditions became more toxic, sampling was as frequent as every five minutes. All of the stations were usually checked on an hourly basis, at which time fish mortality and other visual observations were recorded.

Dissolved oxygen was determined using the azide modification of the Winkler method. One aspect of this method of concern was that interfering substances in the water may have caused the results to be lower or higher than the actual dissolved oxygen present. Reducing substances such as sulfites and iodine absorbing organic material can react with the iodine in the Winkler reagents and give an apparent lower dissolved oxygen value. Oxidizing materials liberate iodine and give an apparent higher dissolved oxygen value (Ross, 1963). Effluents discharged into Everett Harbor contain components from both families of compounds, raising the possibility of error in dissolved oxygen values obtained. Results from a study on dissolved oxygen determination on water containing 100 ppm spent sulfite liquor[1]/ using the Winkler method demonstrated an average error of 1.57 ppm less O_2 in samples of water containing 7.3 ppm oxygen (Baker, 1965).

Test results for dissolved oxygen variance were conducted in 1974 on Everett Harbor water samples using an oxygen probe (IBC dissolved oxygen and temperature monitor field unit) for comparison and dissolved oxygen correction procedures for the Winkler method (Baker, 1965). These test results indicated that no significant deviations from expected dissolved oxygen values were traceable to interfering substances. Therefore, corrections were not made during the remainder of the study on the obtained dissolved oxygen values (Moore, 1982).

Equipment

The holding pen used to acclimate the test fish was constructed of 2-inch PVC pipe made into a framework 3 feet x 3 feet x 4 feet, upon which a rectangular net was secured. A hinged lid fitted with a stainless steel screen was attached to the top of the frame (Figure 3).

Liveboxes were constructed of fiberglass pipe 12 inches in diameter by 18 inches in length. Open ends were covered with small-mesh nylon netting held in place by large rubber bands. When deployed, the livebox assembly was suspended from a long wooden float (Figure 3). The live-boxes were suspended one-half meter below the surface.

RESULTS AND DISCUSSION

Results of the 1981 toxicity study and previous years of study are summarized by area in Table 2 and discussed below:

Area #1

Area #1 demonstrated consistently high mortalities during low tide throughout the eight-year study (Table 2). Refer to Table 3 for appropriate WDOE water quality standard. Table 5 presents the recorded values for bioassay and water quality data. Area #1 had the highest percent mortality of all the areas monitored during the eight-year study period.

1/Spent sulfite liquoe (SSL) is a more descriptive and current term for sulfite waste liquor (SWL).

Hydrogen sulfide toxicity appeared to be the cause of the mortalities. Only two bioassays displayed no mortalities when sulfides were present (Table 4, entry for 06-11-75 and 05-12-76C). Few mortalities were recorded whenever sulfides were not detected. pH, and temperature, were within limits set by the WDOE water quality standards. Dissolved oxygen (D.O.) concentrations were usually within acceptable limits for Class B waters (Table 3). It should be noted that mortalities occurred from one hour before low tide to three hours after. As previously stated, low tide is strongly associated with the release of H_2S gas.

Throughout the ECOBAM bioassay study, gas bubbles containing H_2S and other decomposition products were observed bubbling up through the water column in Study Area #1 (Table 4). Generation of gas was particularly evident adjacent to the Scott Paper Company chip off-loading facility where wood chip transfer takes place from open barges to the pulp paper mill. The transfer process has resulted in a significant addition of settleable solids loading to the immediate receiving waters. During off-loading, a small portion of the chips is lost due to handling. These have settled, and over time apparently have contributed to formation of sludge beds on the bottom. Prior to 1970, the area just north of the chip unloading area was also used to raft logs for the old, small wood mill which discontinued operation in 1970. A log haul for this mill existed on the bank of Area #1. It can be assumed that these activities would have resulted in bark and wood debris settling on the bottom

in this area. Anaerobic decomposition of the chips, bark, and other debris has resulted in the production of soluble sulfides, a percentage of which becomes H_2S.

Studies in Port Angeles Harbor indicate that sulfide levels in excess of 0.3 mg/L resulted in juvenile salmon mortalities (Ziebell, *et al.*, 1970).esults suggest that mortalities in Area #1 coincided with concentrations at or above this level. It should be pointed out that even in the studies where sulfide values were not detected, the small deviation of oxygen concentrations between median and minimum values suggested a reduction in oxygen concentration that may have resulted from the conversion of H_2S (e.g., Table 5 - 05-13-76; Table 8 - 05-14-75). As H_2S becomes oxidized, oxygen levels decline (Cunningham, 1982, personal communication). Some of the data suggest that mortalities occurred when low levels of H_2S were measured (e.g., Table 5 - 06-30-81; 07-01-81). The values may have been an artifact of the sampling techniques employed. Grab samples were employed throughout the study and the water samples may not have contained representative concentrations of H_2S.

Tidal activities can also influence concentrations of hydrogen sulfide. If tides prior to the one in which testing occurred were in the same range, off-gassing may have resulted in a lowering of the quantity of H_2S liberated during the test period. This phenomenon is suggested by the low mortalities during a minus low tide which follow a series of minus low tides that started on 06-07-75 (e.g., Table 5 - 06-11-81; 06-12-81).

In the fall of 1978, the Army Corps of Engineers conducted a dredging operation in the East Waterway to increase the depth of the mid-section by removal of sediments (Figure 1). The dredging operation probably removed a large portion of any sludge beds located in the deeper waters, which may in future years help to improve water quality. However, dredging did not take place in the shallower areas most affected by minus tides -- the areas with the conditions conducive to the release of H_2S in toxic concentrations. Therefore, it appears that sludge beds in Study Area #1 remained untouched and continue to release H_2S at levels similar to those found prior to 1978.

Area #2

Area #2 demonstrated increased survival during the course of the study (Table 2). Table 6 presents the recorded bioassay and water quality data for the study period. Refer to Table 3 for appropriate WDOE water quality standards.

High mortalities were recorded during the early bioassays (Table 6, 05-09-74) when effluent from the Weyerhaeuser sulfite paper mill was observed discharging directly into the livebox deployment area (Table 4). The effluent had a very low pH and mortalities appeared to be due to the discharge (Moore, personal communication, 1982). The data indicate the mortalities were not linked to hydrogen sulfide since none was detected. Later studies displayed 100 percent survival.

Dissolved oxygen and temperature were within acceptable limits for Class A waters. Limits for pH were within acceptable limits

during later studies. However, in 1975 pH exceeded the standard. Discharge of effluent from the Weyerhaeuser sulfite mill may have caused the pH depression. Spent sulfite liquor (Table 3) was detected in the receiving waters by using the Pearl-Benson Index (PBI). Values dropped off substantially during the study period from a high of 750 mg/L in 1975 to 23 mg/L in 1981. In 1975, the pulp mill was converted to a thermo-mechanical mill (T-M) which used heat, pressure, and mechanical means to produce pulp. The result was that spent sulfite liquor was no longer produced and discharged at this site.

During the mid 1970s, several significant changes occurred that reduced effluent loading to Area #2. Major discharges were routed to an on-site treatment facility that included a secondary clarifier used for reduction of total suspended solids. In 1979, storm water collection also was routed to the treatment facility thus eliminating the possibility of settleable solids loading from fiber spills in the mill being flushed into the harbor. These changes in waste treatment appeared to eliminate the toxicity problem in this area. In 1980, due to marketing difficulties, the T-M mill was closed down and Weyerhaeuser ceased all production at this site.

Area #3

Area #3 demonstrated no change in test fish survival during the entire period of the ECOBAM study (Table 2). Throughout the study, mortalities were extremely low; only three deaths were recorded. Table 7 presents the recorded bioassay and water quality data. Refer to Table 3 for applicable WDOE water quality standards.

Water quality data for temperature and dissolved oxygen were within the WDOE water quality standard for Class B waters. pH values were generally within the standard. However, there were episodes when the criterion for pH was exceeded (Table 7, 05-22-74). Total sulfides and spent sulfite liquor were evident; however, values remained low throughout the survey.

Observations by early investigators suggest that a hydrogen sulfide problem existed in Area #3 (Table 4). However, the livebox results did not document a condition as severe as those indicated by visual observations. The shallowness of Area #3 resulted in total exposure of the bottom during minus low tides. Therefore, liveboxes could not be used in the area. However, there appears to be evidence that early in the study H_2S may have been produced in the area. Early investigators noted that in a portion of Area #3 associated with emergency dockside overflows (Figure 1), pulp fiber blanketed the bottom and was actively decomposing. Investigators developed severe headaches and nausea and had to leave the area. Directly next to the shallow area, the bottom dropped off quickly. As the tide would drop, strong currents developed which would dissipate sulfide concentrations (Moore, personal communication, 1982). Inability to further document suspected water quality problems may also have been due, in part, to inherent problems associated with episode testing (see METHODS - Site Selection).

Toxicity studies in Area #3 were discontinued after 1978. All discharges to the area have been re-routed to treatment facilities

(Table 1). A followup study in 1981 could not be carried out because the area has been filled.

Area #4

Area #4 demonstrated no change in toxicity during 1977, 1978, and 1981. Comparison with 1974, 1975, and 1976 studies suggests an increase in mortality with time (Table 2). The increase probably resulted from changing livebox locations as previously discussed in METHODS on Page 3 and shown on Figure 2. Mortality remained at 30 percent or above in this study area during 1977 and 1981. There were zero mortalities in 1978.

Temperature and dissolved oxygen were within WDOE water quality standards for Class B waters during the study (Tables 3 and 8). pH levels were not within compliance on four occasions, three of which were associated with high mortalities in livebox test fish. Testing for total sulfides indicated no sulfides present during the bioassays. Free chlorine was detected in the area in 1977 during two bioassay studies and chlorine odor was also detected by the investigators (Table 4, Area 4). This suggests that chlorine may have contributed to the 1977 mortalities. The source of the chlorine was most likely the Scott Paper Company bleach plant discharge (002). Further mortalities were recorded during 1981, which suggested pollutants were still present in the discharge. (Refer to the discussion on effluent toxicity that follows Area #6 results.) Chlorine was not detected during the 1981 study. Bleach plant

effluent was diverted to the new secondary treatment system beginning January 1, 1980. This suggests that other toxic components were contained in the effluent from outfall 003, the main dockside diffuser.

Mortalities were observed for as long as two hours and 45 minutes after low tide. Studies of 24-hour duration resulted in further mortalities up to 20 percent. Area #4 had the second highest percent mortality of any area studied.

During July of 1973, CH_2M Hill, Inc., an environmental consulting firm, conducted a diffuser adequacy study for Scott Paper Company in the Everett East Waterway. Bioassay studies were carried out in the area associated with the Scott main diffuser (outfall 003) (Area #4 of the ECOBAM bioassay study). The results of CH_2M Hill's study indicated no acute toxicity as a result of mill discharges during the 48-hour study period. Stations located within the dilution zone displayed no acute toxicity or acute biological shock. Indigenous fish were observed swimming in the vicinity of the dockside diffuser during the study period.

The CH_2M Hill results compare favorably with those from the 05/13/76 ECOBAM study that displayed almost no mortalities during the 24-hour study period (Table 8). However, it should be noted that the bioassay tests dealt with a short period of time -- 24 to 48 hours. It is possible that episodes such as process changes, plant upsets, and other events that could have led to release of compounds toxic to test organisms were missed. During the six years in which bioassays were conducted by WDOE, four of the liveboxes

displayed 100 percent mortality; the 6/30/81 study indicates toxic episodes continued to occur in Area #4 since 30 percent of the test organisms died during the study. Indigenous juvenile salmon were observed in the area during the 06/04/74 bioassay when livebox A displayed 100 percent mortality and liveboxes B, C, D, and E experienced zero mortality. This may indicate that toxic effects decrease very rapidly relative to the distance from the diffuser.

Area #5

Area #5 demonstrated no mortalities during the 1981 study (Table 2). Comparison with previous studies was not possible because this was the first time the area was studied. Secondary treatment plant effluent began being discharged into this area on January 1, 1980.

Low concentrations of dissolved sulfides indicated the presence of hydrogen sulfide (Table 9). In addition to decomposition of bottom sludges, a storm water outfall draining the fill area north of the East Waterway is a potential source of H_2S. This outfall was installed for surface storm water from the new fill. As this area has not been paved, little surface water enters the storm sewer. The H_2S is due to infiltration of groundwater contaminated by sludge fill material dredged from the waterway. Dredge spoils were placed in the bottom of the fill and then covered with clean upland fill material (Wright, personal communication, 1982). However, no mortalities occurred.

During the survey, dissolved oxygen, pH, and temperature were within limits for WDOE water quality standards for Class B waters

(Table 3). The results during the testing period did not suggest any toxicity associated with discharges within Area #5.

Scott Paper Company bioassay test results using rainbout trout in solutions of 65 percent effluent and 35 percent freshwater imply that toxic episodes could occur in Area #5 as a result of effluent discharges. Further receiving water bioassay studies would be appropriate to determine if mortalities are occurring in the harbor due to the discharge. (Refer to the discussion following the Area #6 results.)

Area #6

Area #6 demonstrated no mortalities during the 1981 study. Comparison with previous studies was not possible because this was the first time the area was used as a control. Lack of mortalities also suggests that the transfer process did not increase the mortality rate at other stations since these test fish were held the longest during the transfer process.

Sulfides were not detected at this location (Table 9). During the survey, dissolved oxygen, pH, and temperature were within limits for WDOE water quality standards for Class B waters (Table 3).

Effluent Bioassays by Scott and Weyerhaeuser

In the WDOE National Pollutant Discharge Elimination System (NPDES) waste discharge permit, toxicity monitoring is required to ensure an 80

percent survival rate of juvenile salmon in 96-hour bioassay tests done in 65 percent effluent. The bioassays are carried out on a monthly basis. Table 10 is a summary of the bioassays conducted by Scott Paper during 1980 and most of 1981 on outfalls 001, 003, Benson sewer (a trunk line to 003), and 008. Results indicate that on numerous occasions bioassay results did not comply with the NPDES permit limitations. Results from the Benson sewer and 003 outfall bioassays and the WDOE 1981 bioassay study for Area #4 all demonstrated mortalities during testing which indicates that toxic pollutants were being discharged at 003 after primary treatment had been applied. The burning of tires in the hogged fuel boilers during 1981 may have contributed to mortalities by the introduction of zinc to process water used to quench hot cinders and flash in air pollution control equipment (Bishop, 1981). The process water is then routed to the primary clarifier and discharged through 001 and 003. A system to remove zinc from the effluents was being designed for installation in mid-1982 (Bechtel, personal communication, 1982). Bishop stated that bioassays carried out on effluent from outfall 004 (Area #3) did not produce any mortalities. WDOE bioassay test results for Area #3 demonstrated almost no mortalities during the course of the ECOBAM study. It should be pointed out that bioassays carried out on the 008 effluents also displayed mortalities during 1980 and 1981 but were not substantiated by mortalities found during the WDOE 1981 study. In late 1981, Scott determined that ammonia was the cause of the toxicity associated with 008 effluents. Excess ammonia use in the treatment plant was minimized and no bioassay mortalities have occurred since October 1981 (Bechtel, personal communication, 1982). The failure to observe mortalities during this study may have been due to receiving water dilution reducing effluent toxicity.

Bishop further stated that effluent bioassays were not carried out on the Weyerhaeuser Company sulfite discharge(s) (ECOBAM Area #2). How-

ever, bioassays were conducted on the Weyerhaeuser effluent after conversion to thermomechanical pulp processing with secondary effluent treatment. The conversion occurred in 1975 and bioassays on final effluent demonstrated 100 percent survival of juvenile salmon in 65 percent effluent for 96 hours. The ECOBAM bioassays indicated increased survival up to 100 percent in this area during the course of the study, as discussed in Area #2 results.

CONCLUSIONS

Three study areas within the Everett East Waterway displayed few or no mortalities during the entire bioassay testing period. These included areas 3, 5, and 6. Early-on studies in Area #3 indicated low mortalities in an area of the harbor closely associated with industrial usage including wastewater discharge and settleable solids loading. Area #3 fish survival remained at nearly 100 percent during the five years of study (1974-1978). Tests conducted in 1981 in Area #5 demonstrated 100 percent survival in an area of the Everett harbor associated with discharge of secondary treated effluents. Studies carried out in Area #6 during 1981 demonstrated 100 percent survival in an area of the harbor not associated with discharges or other major pollutant sources. It appears that toxicity is localized and mortalities decrease rapidly with distance from sludge beds or outfalls.

Fish survival within Area #1 and Area #4 did not demonstrate a significant overall change during the 1974 through 1981 studies. Area #1 mortalities remained at nearly 100 percent throughout the study period and appear to have been caused primarily by hydrogen sulfide released

during low tides. Low mortalities in Area #3 (Table 2) which is located in close proximity to Area #1 suggests that toxicity in Area #1 is confined to a relatively small area and that mortality decreases rapidly relative to distance from the source of H_2S production (woodchip-sludge beds). Improvements in chip handling such as a large, movable apron to prevent chips from falling into the water has decreased the solids loading to the area. However, hydrogen sulfide generation will remain elevated in this area for an indefinite period due to the sludge beds already built up by previous loading that are capable of long-term H_2S production. Recent dredging operations (1977) within the waterway by the Army Corps of Engineers did not remove a significant amount of material from the sludge beds adjacent to the chip loader and the old log haul and log rafting area. ECOBAM bioassay studies conducted since the dredging do not show any change in H_2S toxicity in the area. Area #4 mortalities remained at 30 percent or above during the study. The mortalities appear to be associated with effluent discharged from the Scott Paper Company diffuser (outfall 003).

Fish survival outside the Class B designated waters in Area #2 (Class A water) has demonstrated a significant increase since the inception of the study, from zero in 1974 to 100 percent in 1981. The increased survival is a result of changes in the location of effluent discharge for Weyerhaeuser Company, new construction in the area by Weyerhaeuser that may have displaced sludge beds associated with chip off-loading practices, and discontinued use of the adjacent on-shore site for pulp production. Sulfides were not detected in Area #2 during the most recent bioassay tests.

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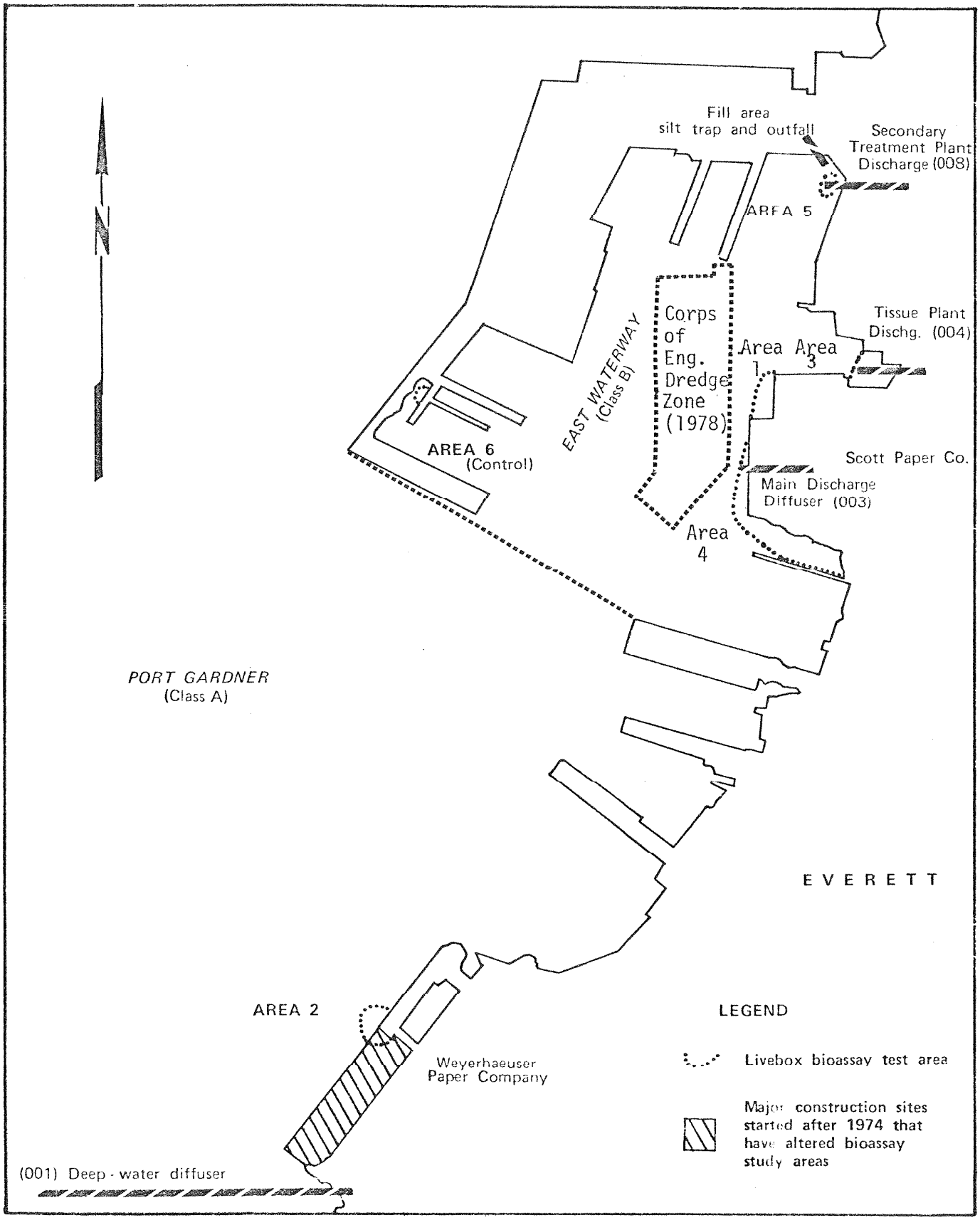


FIGURE 1. Livebox bioassay test area 1 - 6 in the East Waterway of Everett Harbor.

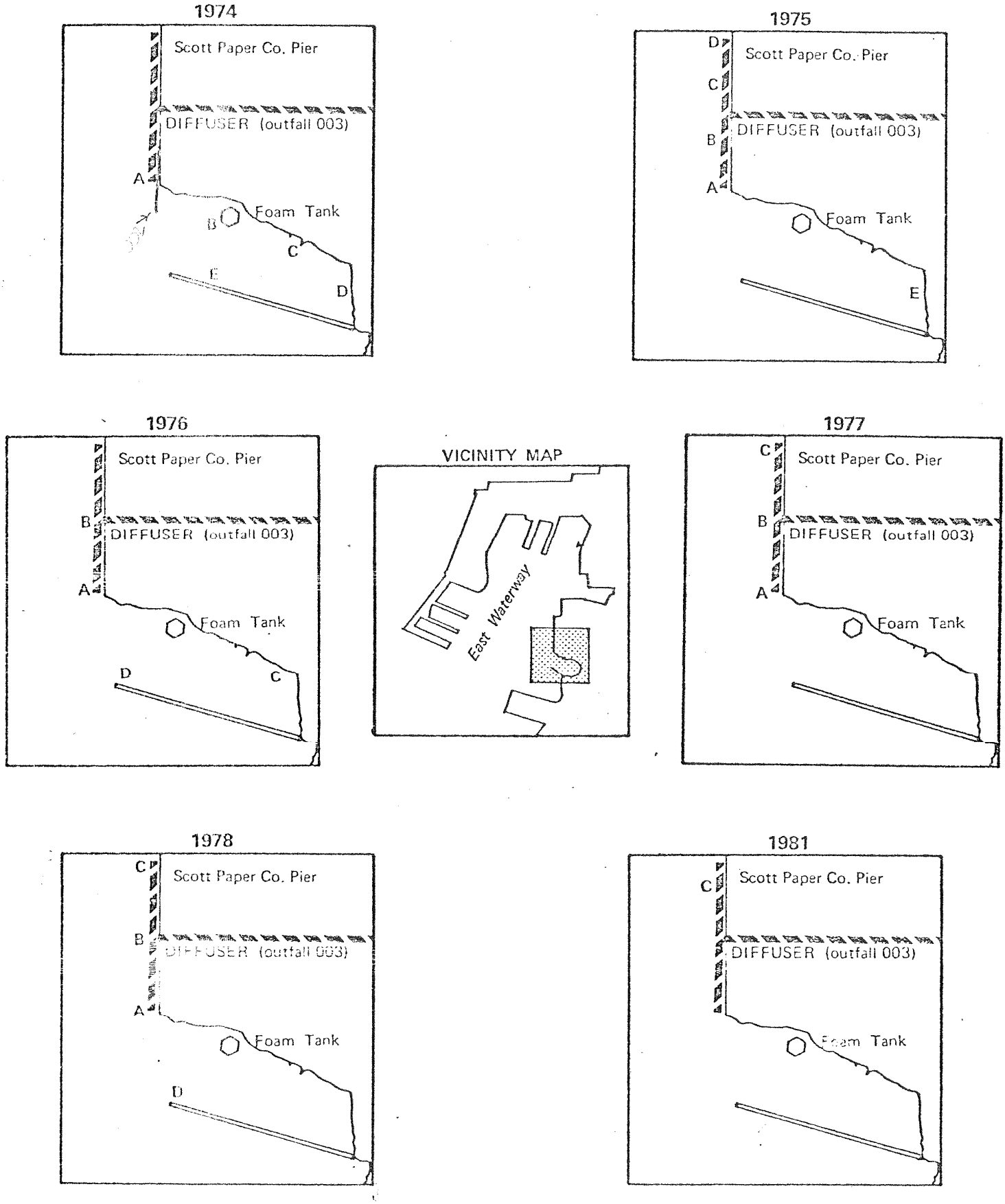
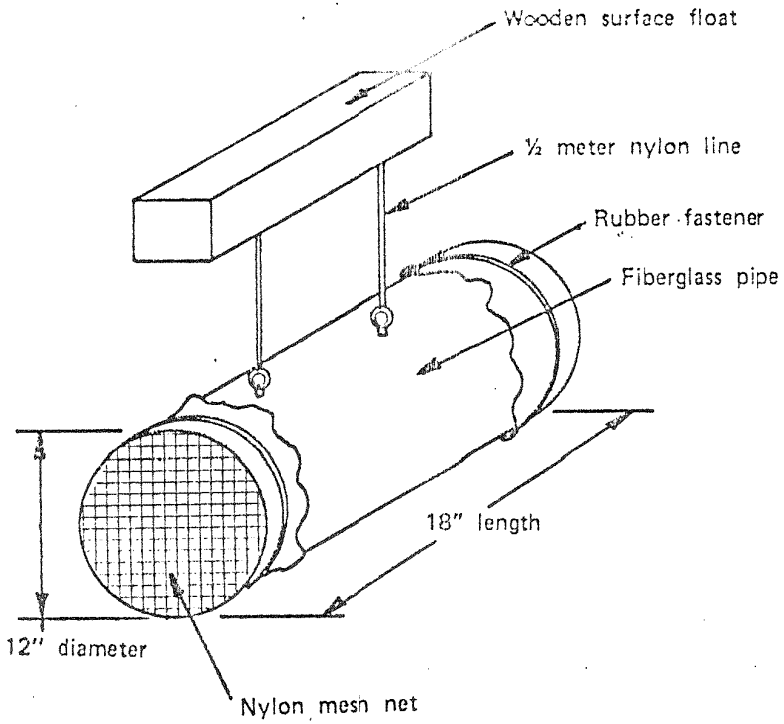
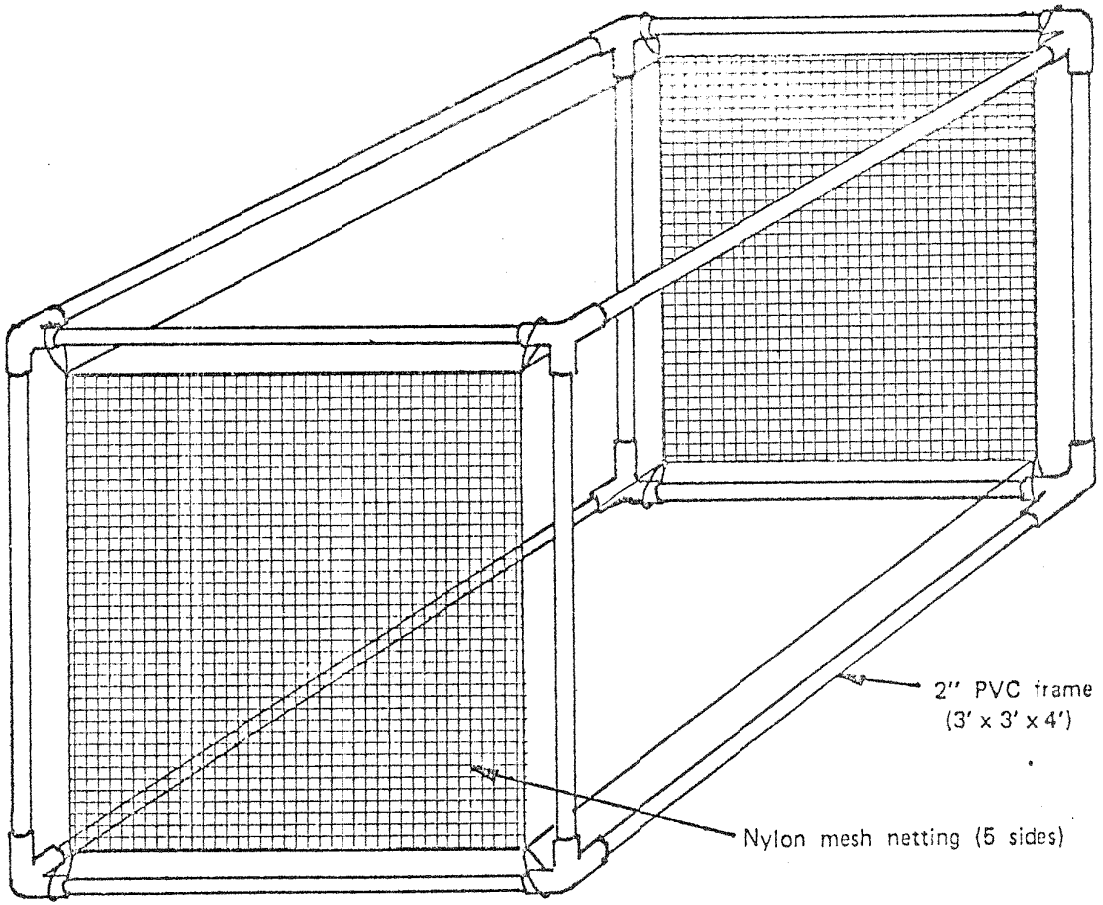


FIGURE 2. Schematic diagram of livebox bioassay area no. 4 depicting changes in livebox sites during the 1974 - 1981 ECOBAM fish toxicity study



1. LIVEBOX



2. HOLDING PEN (hinged cover not shown)

FIGURE 3. Diagrams of bioassay livebox and holding pen used during ECOBAM livebox bioassay study, Everett, Washington, 1974 - 1981.

Table 1. Area site selection criteria including descriptions of industrial outfalls in the Everett East Waterway and vicinity.

Test Area Description	Reason for Sampling Site Location	Description of Outfalls Associated with Sampling Sites
Area #1 - North end of Scott Paper Company pier adjacent to the chip offloading crane and chip conveyer.	Located near suspected sludge beds composed of wood ships and other settleable solids.	N/A
Area #2 - South end of original Weyerhaeuser pier prior to construction of the new paper loading facility.	Located near a Weyerhaeuser discharge pipe that was taken out of service in 1975 when a new treatment facility was built. Discharge then took place through a deepwater diffuser (outfall 001). Bioassays were discontinued after 1975 due to construction of a new pier and warehouse facility south of the original Weyerhaeuser pier (Figure 1).	Outfall 001 - Deepwater diffuser located 1,000 yards due west of the Weyerhaeuser pulp mill. The waste stream included a portion of the treated process water from the Scott first clarifier and the waste water from the Weyerhaeuser mill. Mill ceased operation in December 1980.
Area #3 - Small embayment located between Scott Paper Company's original facilities and the tissue plant.	Located adjacent to the Scott Paper Company diffuser (004) used for discharging a waste stream containing chlorine. Was filled in by Scott Paper Company in 1978 to increase the size of the plant site (Figure 1).	Outfall 004 - Discontinued in April 1981. The discharge was from the Scott Paper tissue bleach plant. The process water is now routed to the first clarifier and discharged at 003 after treatment.
Area #4 - South end of Scott pier and adjacent to the pier and the main diffuser.	Located adjacent to the Scott Paper Company diffusers (002) and (003) (Figure 1).	
	Scott diffuser (002) discharged wastewater from the chlorinated washer used in the pulp bleaching process.	Outfall 002 extends parallel to and beyond the southwest corner of the Scott pier. This dockside diffuser carried wastewater from the chlorinated washer for pulp bleaching (chlorine source). This outfall was sporadic in nature, with a bright orange-brown colored effluent. The discharge was discontinued when the bleach plant effluent was diverted to the new secondary treatment system beginning January 1, 1980.
	(003) is used for discharging various treated effluents from the Scott pulp mill and surface water from the Benson sewer.	Outfall 003 is a diffuser that is located along the southern two thirds of the Scott Paper Company pier. Treated waste water from the first primary clarifier is discharged through the diffuser after passing through a weir that splits the stream sending part of it through the diffuser and the remainder to the deepwater diffuser 001. The clarifier removes suspended solids from the stream which is then treated with caustic soda to raise the pH level prior to discharge to the inner harbor. Stormwater is also discharged at 003 by way of the Benson sewer that connects to waste stream prior to discharge.

Table 1. - Continued.

Test Area Description	Reason for Sampling Site Location	Description of Outfalls Associated with Sampling Sites
Area #5 - Northeast terminus of the East Waterway.	Was added to the bioassay study in 1981 to monitor new discharges to Everett Harbor by the City of Everett and Scott Paper company (Figure 1). The new City of Everett discharge is associated with a major tideland-fill project located north of the East Waterway. Water draining from the fill area is directed to a silt trap and then discharged into the northern end of the waterway. The silt trap was constructed in the spring of 1980. Treated process water is discharged into the upper end of the waterway through a diffuser (outfall 008).	Outfall 008 - Diffuser for the Scott treatment plant located at the northern terminus of the waterway. Put on line in the spring of 1980. Spent sulfite liquor* and other used components are treated in the plant using the activated sludge process and aeration basins prior to discharge.
Area #6 - South end of the Snohomish River/ East Waterway jetty.	Served as the control in 1981. The control was used to assess stress to juvenile salmon as a result of capture, holding, and transfer activities (Figure 1). The area was chosen due to its protected environment and the presence of juvenile salmon feeding in the area during all tide stages.	N/A

*Spent sulfite liquor (SSL) is a more descriptive and current term for sulfite waste liquor (SWL).

Table 2. Summary of juvenile salmon livebox study. Results showing percent mortality by area and date for Everett Harbor ECOBAM study (1974-1981).

Area #1 (North end of the Scott Paper Co. pier adjacent to the chip offloading crane and chip conveyer)				Area #2 (South end of original Weyerhaeuser pier prior to construction of the new paper loading facility)				Area #3 (Small embayment located between Scott Paper Company's original facilities and the tissue plant [outfall 004])			
	Number Stations	% Mortality			Number Stations	% Mortality			Number Stations	% Mortality	
Test Date	/Area	$\bar{X}$	All[1] Only	Test Date	/Area	$\bar{X}$	All[1] Only	Test Date	/Area	$\bar{X}$	All[1] Only
05/02/74	5	0	0	05/02/74	5	0	0	05/16/74	5	0	0
05/09/74	5	96	100	05/09/74	4	75	100	05/22/74	5	6	0
								06/06/74	5	0	0
06/10/75	5	100	100	04/29/75	4	0	0	06/11/75	5	0	0
06/11/75	1	0	0	04/30/75	4	32.5	100				
06/12/75	4	0	0								
05/12/76	5	40	100	05/13/76	4	0	0	06/09/76	5	0	0
05/13/76	4	0	0	06/09/76	1	20	20				
06/09/76	4	65	100								
05/02/77	5	22	100					05/03/77	5	0	0
05/31/77	5	60	100								
04/25/78	5	26	20					04/24/78	5	0	0
05/08/78	5	82	100								
06/06/78	6	0	0								
06/30/81	1	100	100	06/30/81	1	0	0	(Note: Area #3 has been back-			
07/01/81	1	100	100	07/01/81	1	0	0	filled by Scott Paper Company)			

[1] Main station sampled for chemical data during observation of liveboxes.

Table 2. - Continued.

Area #4 (South end of Scott pier and adjacent to the pier and the main diffuser [outfall 003])				Area #5 (Northeast terminus of the east waterway [outfall 008])				Area #6 (South end of the Snohomish River/East Waterway jetty)			
	Number Stations	% Mortality			Number Stations	% Mortality			Number Stations	% Mortality	
Test Date	/Area	$\bar{X}$	C Only	Test Date	/Area	$\bar{X}$	A[1] Only	Test Date	/Area	$\bar{X}$	A[1] Only
06/04/74	5	20	0	(Areas #5 and #6 added in 1981. No previous data.)							
05/14/75	5	2	10								
05/12/76	1	0	---								
05/13/76	4	0	0								
05/24/77	3	33	100								
06/01/77	2	50	100								
04/26/78	4	37.5	50								
05/09/78	3	0	0								
06/05/78	3	0	0								
06/30/81	1	30	30	06/30/81	1	0	0	06/30/81	1	0	0
				07/01/81	1	0	0	07/01/81	1	0	0

[1] Main station sampled for chemical data during observation of liveboxes.

Table 3. Parametric coverage and rationale for measuring each during ECOBAM livebox bioassay study in Everett Harbor.

Parameter	Location	Method	Reason for Sampling	Water Quality Standard (Class A) (Port Gardner)	Water Quality Standard (Class B) (East Waterway)
Temperature (°C)	All receiving water stations	Thermometer	Used with salinity to determine water density; temperature also affects gas solubility and rates of biological processes.	Not to exceed 16°C due to human activities. ($t = 12/[T-2]$)	Not to exceed 19°C due to human activities. ($t = 16/T$)
Salinity (0/00)	All receiving water stations	Beckman induction salinometer	Used to trace passage of fresh-water through marine waters, mixing rates, and density distribution in water column.	No standard.	No standard.
Dissolved O_2 (mg/L; % saturation)	All receiving water stations	Winkler - azide modification (APHA, AWWA, and WPCF, 1976; EPA, 1979).	Elevated, relatively constant oxygen levels are essential for stable marine communities. Highly variable levels downstream from a source may be indicative of an organic load in excess of the ability of the system to assimilate it.	Shall exceed 6.0 mg/L, except where upwelling occurs; natural D.O. may be degraded by up to 0.2 mg/L by man-caused activities.	Shall exceed 5.0 mg/L or 70% saturation whichever is greater, except when the natural phenomenon of upwelling occurs. Natural D.O. levels can be degraded by up to 0.2 mg/L by man-caused activities.
Biochemical Oxygen Demand (mg/L)	Effluent	WDOE 1977	Measures the dissolved oxygen consumed by micro-organisms while assimilating and oxidizing the organic matter in a sample over a fixed period of time (usually 5 days).	N.A.	N.A.
pH (S.U.)	All stations	Orion digital pH meter	pH affects the carbonic acid-carbon dioxide balance in sea-water. pH also affects the activity of un-ionized ammonia and sulfide. EPA (1976) recommends pH values be within 6.5 to 9.0 pH units.	Within range of 7.0 to 8.5 with man-caused variations within a range of 0.5 unit.	Shall be within the range of 7.0 to 8.5 with a man-caused variation within a range of less than 0.5 unit.
Total Residual Chlorine (mg/L)	All stations	LaMotte-Palin DPD field test kit (0.1 ppm minimum detectable level).	Chlorine is used as a bleaching agent in the paper pulping process for sulfite mills and is discharged in the wastewater stream. It is also toxic to marine organisms. EPA (1976) recommends an upper limit of 2.0 ug/L for salmonid fish and 10.0 ug/L for other freshwater and marine organisms. AFS (1979) suggests that 20 ug/L for total oxidarts is the best marine criterion at present.	Toxic, radioactive, or deletrious material concentrations shall be below those of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.	Toxic, radioactive, or deletrious material concentrations shall be below those which adversely affect public health during characteristic uses, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect characteristic water uses.

Table 3. - Continued.

Parameter	Location	Method	Reason for Sampling	Water Quality Standard (Class A) (Port Gardner)	Water Quality Standard (Class B) (East Waterway)
Turbidity (NTU) Total Susp. Solids (TSS, mg/L)	All receiving water stations	Turbidity: Hach Turbidimeter; TSS: APHA (1975), EPA (1979)	Measures water column transparency, light availability, and is an estimate of suspended material in water column. Sufficient light is essential to marine plant growth. Excessive suspended material may stress bottom-dwelling plants and animals by interference in filter feeding, and by light reduction, or smothering. Turbidity is a function of quantity and light scattering characteristics of the suspended material.	Not to exceed 5 NTU over background if background is 50 NTU or less or have more than a 20% increase in turbidity when the background turbidity is more than 50 NTU.	Not to exceed 10 NTU over background if background is 50 NTU or less or have more than a 20% increase in turbidity when the background turbidity is more than 50 NTU.
Total Suspended Solids (TSS) (mg/L Volatile Solids (mg/L)	Discharge zone, all receiving water stations	Oven dry @ 105°C to determine TSS further analysis at higher temp (550°C) in a muffle furnace determines vilatile solids and non-volatile solids (APHA, 1975).	Determine the effect on aquatic system as a result of reduced light for photosynthesis of plants and the adverse affects to aquatic organisms such as reduction of food availability, reduction in growth rate, prevention of successful early development.	No standard.	No standard.
Secchi Depth (m)	Discharge zone, ambient stations	Secchi disc lowered to depth of disappearance	Refer to Turbidity comments above.	No standard.	No standard.
Sulfite Waste Liquor (SWL) (mg/L)	All stations	Pearl-Benson Index (PBI): Perkin Elmer 360 Atomic Absorbtion Spectrophotometer	SWL is a byproduct of the manufacture of paper from wood by the sulfite process. It also has a high oxygen demand (BOD) requirement when introduced into a receiving water. This results in a depletion of available oxygen for organisms in the system.	Toxic, radioactive, or deletrious material (refer to Total Residual Chlorine for definition).	Toxic, radioactive, or deletrious material (refer to Total Residual Chlorine for definition).
Dissolved (S^{-2}) Sulfides (mg/L)	All stations	LaMotte-Pomeroy sulfide test kit	Dissolved sulfides indicate the presence of breakdown products from H_2S production by anaerobic bacteria in sediments (EPA, 1976).	Toxic, radioactive, or deletrious material (refer to Total Residual Chlorine for definition).	Toxic, radioactive, or deletrious material (refer to Total Residual Chlorine for definition).

Table 3. - Continued.

Parameter	Location	Method	Reason for Sampling	Water Quality Standard (Class A) (Port Gardner)	Water Quality Standard (Class B) (East Waterway)
Total Sulfides (TS) (mg/L)	All stations	LaMotte-Pomeroy sulfide test kit	Total sulfides indicate the presence of sulfides from all sources including breakdown products from bacterial action, industrial effluents, and municipal sewage.	Toxic, radioactive, or deletrious material (refer to Total Chlorine Residual for definition).	Toxic, radioactive, or deletrious material (refer to Total Chlorine Residual for definition).
Hydrogen Sulfide (H_2S) (mg/L)	All stations	LaMotte-Pomeroy sulfide test kit	H_2S concentrations are a function of pH, temperature, and salinity. EPA (1976) recommends an upper limit of 2.0 ug/L undissociated H_2S for fish and other aquatic life, fresh and marine water.	Toxic, radioactive, or deletrious material (refer to Total Residual Chlorine for definition).	Toxic, radioactive, or deletrious material (refer to Total Residual Chlorine for definition).

Table 4. Observations in Everett Harbor during *in situ* bioassay studies, 1974-1981.

Area	Station	Date	Time of Observation	Low Tide (Time)	Low Tide (Height)	Observation
1	A	05/08/74	--	1147	-1.6	H_2S bubbling in all livebox areas, milky appearance of water near shore. Strong H_2S odor near main box.
1	A	05/08/74	1200	1147	-1.6	Several small schools of juvenile salmon seen in area; starry flounder approximately 30 cm distressed on surface.
1	C	05/08/74	1200	1147	-1.6	Small schools of juvenile salmon in area, some appear distressed total sulfide 5.8 mg/L).
1	E	05/08/74	1000	1147	-1.6	School of approximately 150 juvenile salmon; dip net three pink salmon (total sulfide >0.0 mg/L).
1	A	06/10/75	--	1151	-2.2	Warm, overcast, light northwest breeze. 30 minutes before first mortalities several larger schools of juvenile chum salmon were observed (approximate size 5-7 cm/fish). At 1115 heavy H_2S odor.
1	A	06/11/75	--	1232	-2.5	Sunny, light north wind; minimal bubbling at low tide; white sludge deposits visible on bottom throughout area. Free-swimming chum fry seen in area at 1200 when sulfide levels were at 0.2 mg/L. Large herring school (approximately 5,000) seen at Station A at 1230.
1	B	05/12/76	0915	1028	-1.5	Detectable odor and bubbling on water; school of approximately 25 juvenile salmon. At 1015 one sculpin on surface under stress.
1	D	05/12/76	0955	1028	-1.5	School of approximately 12 juvenile salmon near livebox appeared normal.
1	D	06/09/76	0815	0911	-1.4	Two dead hake; H_2S odor.
1	A	05/02/77	1000	1037	-.7	Bubbling throughout area; H_2S smell strong.
1	B	04/25/78	1000	1207	-1.8	School of juvenile salmon by station.
1	B	04/25/78	1230	1207	-1.8	Heavy bubbling occurring in area.
1	A	05/08/78	--	1223	-0.9	Extremely high H_2S problem today; large, concentrated milky clouds drifting about livebox areas; high H_2S odor.
1	A	06/06/78	1035	1159	-1.3	Very fast current; no bubbles visible; many juvenile salmon spotted throughout area.
1	A	06/06/78	1235	1159	-1.3	No heavy bubbling or other indications of H_2S today; water very clear.
1	A	06/30/81	1100	1018	-2.8	Heavy bubbling; all fish relatively vigorous.

Table 4. - Continued.

Area	Station	Date	Time of Observation	Low Tide (Time)	Low Tide (Height)	Observation
2	A	05/09/74	1240	1226	-1.2	Discharge plume from Weyerhaeuser sulfite mill flowing directly through livebox.
	A	05/09/74	1353	1226	-1.2	Dead bioassay juvenile salmon have the color of metallic blue-green.
	B	05/09/74	--	1226	-1.2	During ebb tide, current was observed to flow to the north, away from the liveboxes. As low tide approached and the current slowed, the effluent started spreading into the liveboxes and mortalities began and continued as the current switched to a southerly flow during incoming tide.
2	A	06/30/81	1050	1018	-2.8	No bubbling; juvenile salmon observed feeding in area.
3	C	05/16/74	1030	0703	3.2	Intermittent to constant discharge of dyed, steaming, pulp-rich water discharging from two dockside overflows during the survey. Estimated 0 to 500 gallons per minute.
3	D	05/16/74	1030	0703	3.2	Three pumps are used to pump process water to clarifier. During the survey, one was replaced and apparently all process water was discharged through the two dockside emergency overflows. This occurred during a time period when all three pumps were shut down at approximately 1500 to 1515 hours. Surface water temperatures rose quickly. Water around boxes C and D became very thick with suspended, dyed pulp. No ill effects were noted in the fish.
3	A	05/22/74	--	1047	-2.9	H_2S smell and bubbling noticed by 1100. Many fish observed inside line of A, B, C at 0930; all fish in area had disappeared by 1047.
3	B	05/27/74	1100	1047	-2.9	Seagulls on east shore inside A, B, C, demarcation line, picking up what appears to be dead fish. Survey of area at 1620 turns up one dead chum salmon fingerling; no external marks; found lying on white-sludge bottom of thick pulp.
3	C					Small school of chum salmon fingerlings were observed swimming near livebox station C. They appeared to be stressed, displaying erratic swimming behavior. Total sulfices measured at 3.0 mg/L.
3	D	05/27/74	1040	1047	-2.9	Profuse H_2S bubbling and odor noted by 1040.
3	E	05/22/74	1315	1047	-2.9	Juvenile salmon school (approximately 1,000) observed near clarifier pumps (see map) at 1315.

Table 4. - Continued.

Area	Station	Date	Time of Obser-vation	Low Tide (Time)	Low Tide (Height)	Observation
3	A,B	06/09/76	0700	0912	-1.4	Heavy bubbling at sations A and B; none at C and D. Juvenile salmon jumping at B and D.
3	C,D	06/09/76	0800	0912	-1.4	Bubbling at C; juvenile salmon still at C and D.
3	A,B,C,D	06/09/76	0825	0912	-1.4	Heavy bubbling at A,B,C,D; H_2S odor; juvenile salmon among bubbles at B.
3	A,B,C,D	06/09/76	1019	0912	-1.4	Bubbling negligible; juvenile salmon at B.
3	E	04/24/78	0930	1212	-1.4	School of juvenile salmon (approximately 200) observed near station E. Behavior appears normal. Bubbling observed in area.
4	B	06/04/74	1022	1013	-1.9	Approximately 50 juvenile salmon 4 to 5.5 cm in length in immediate vicinity.
4	C	06/05/74	0944	1013	-1.9	Caustic spill in immediate vicinity of livebox; pH measured at 10.2; no apparent mortalities.
4	C	05/24/77	1425	1548	.9	Surface boil from dockside diffuser; free Cl_2 measured .5 mg/L (effluent originates from Scott bleach plant).
4	C	06/01/77	0900	1109	-2.8	Heavy boil from bleach plant diffuser; chlorine smell.
4	C	06/01/77	1110	1109	-2.8	Brown effluent on surface; chlorine odor not evident.
4	C	06/05/78	1330	1125	-1.2	No discharge visible from Scott diffuser; water appears to be clear near dock.
4	C	06/30/81	1050	1018	-2.8	Discharge from diffuser evident; some bubbling from sediment.

Table 5. Livebox bioassay and water quality data for ECOBAM study, 1974-1981, Area #1 (north end of the Scott Paper Company pier adjacent to the chip offloading crane and chip conveyer).

Area	Station	Date	% Mortality[1]	Exposure Time (minutes)	LT ± T (minutes)	Low Tide Time	Low Tide Feet	Diss. Sulfides (S^{-2}) (mg/L)	H_2S Determined from S^{-2} (mg/L)	T. Sulfide (mg/L) Max.	T. Sulfide (mg/L) Med.	PBI (mg/L) Min.	PBI (mg/L) Med.	D.O. (mg/L) Min.	D.O. (mg/L) Med.	pH (S.U.) Min.	pH (S.U.) Med.	Salinity (O/OO) Med.	Temp. (°C) Med.	Comments
1	A	05/02/74	0	150	+191	0849	+1.7	--[3]	--	0	0	33	26.5	7.8	8.0	--	--	20	10.0	
	B		0	120	+191			--	--	--	--	--	--	--	--	--	--	--	--	
	C		0	120	+191			--	--	--	--	--	--	--	--	--	--	--	--	
	D		0	120	+191			--	--	--	--	--	--	--	--	--	--	--	--	
	E		0	120	+191			--	--	--	--	--	--	--	--	--	--	--	--	
1	A	05/08/74	100	120	+13	1147	-1.6	--	--	1.1[4]	--	95[4]	--	8.8[4]	--	--	--	15[4]	--	
	B		100	150	+13			--	--	--	2.9	--	--	6.6	--	--	--	15	--	
	C		100	204	+67			--	--	--	5.8	--	--	6.3	--	--	--	15	--	
	D		80	307	+170			--	--	--	2.5	--	--	--	--	--	--	--	--	
	E		100	411	+244			--	--	--	0.0	--	--	--	--	--	--	16	--	
1	A	06/10/75	100	110	-1	1151	-2.5	--	--	--	>0.0[5]	59	45	8.9	9.5	--	--	17.2	15.0	
	B		100	65	-46			--	--	--	>0.0[5]	--	--	--	--	--	--	--	--	
	C		100	65	-46			--	--	--	>0.0[5]	--	--	--	--	--	--	--	--	
	D		100	110	-1			--	--	--	>0.0[5]	--	--	--	--	--	--	--	--	
	E		100	135	+24			--	--	--	>0.0[5]	--	--	--	--	--	--	--	--	
1	A	06/11/75	0	120	+88	1232	-2.5	--	--	0.2	0.2	41	36	7.8	8.7	7.7	7.6	--	16.3	
1	B	06/12/75	0	270	+197	1313	-2.2	--	--	--	--	--	--	--	--	--	--	--	--	
	C		0	270	+197			--	--	--	--	--	--	--	--	--	--	--	--	
	D		0	270	+197			--	--	--	--	--	--	--	--	--	--	--	--	
	E		0	270	+197			--	--	--	--	--	--	--	--	--	--	--	--	
1	A	05/12/76	100	150	+7	1028	-1.5	--	--	1.4	0.2	14	9	11.1	11.3	7.3	7.8	14.7	10.9	
	B		100	125	-13			--	--	2.0	1.6	--	--	10.2	10.6	7.1	7.5	15.1	11.0	
	C		0	180	+47			--	--	0.5	0.3	--	--	10.2	11.1	7.7	7.9	14.9	10.9	
	D		0	175	+47			--	--	0	0	--	--	11.1	11.4	7.1	7.9	15.1	10.8	
	E		0	175	+52			--	--	0	0	--	--	10.6	11.6	8.2	8.0	15.0	10.8	
1	A	05/13/76	0	120	-2	1102	-2.4	--	--	0	0	14[4]	--	10.7	10.8	8.0	8.1	14.7	10.9	24-hr. mort. 0%
	B		0	140	+8			--	--	0	0	--	--	10.6	11.0	8.1	8.1	14.8	11.4	24-hr. mort. 0%
	C		0	130	+13			--	--	0	0	--	--	10.5	10.8	8.1	8.2	16.0	10.9	24-hr. mort. 10%
	D		0	130	+18			--	--	0	0	--	--	10.6	11.3	7.8	8.0	15.0	10.8	Fish escaped
1	A	06/09/76	100	95	+9	0911	-1.4	--	--	1.5	1.1	--	--	5.0	8.5	7.1	7.3	17.9	12.4	
	B		100	115	+4			--	--	4.0	1.1	--	--	--	--	7.1	7.4	17.9	12.9	
	C		60	148	+52			--	--	1.3	0.7	--	--	--	--	7.2	7.5	17.7	12.5	
	D		0	153	+49			--	--	0	0	--	--	--	--	7.0	7.4	17.7	12.5	

[1] Ten salmon per sample.

[2] Time before (-) or after (+) low tide when the last observation of the first set of test organisms was made.

[3] -- = No data.

[4] Not a median - single sample only.

[5]

Table 5. - Continued.

Area	Station	Date	% Mortality[1]	Exposure Time (minutes)	LT ± T (minutes)	Low Tide Time	Low Tide Feet	Diss. Sulfides (S^{-2}) (mg/L)	H_2S Determined from S^{-2} (mg/L)	T. Sulfide (mg/L) Max.	T. Sulfide (mg/L) Med.	PBI (mg/L) Min.	PBI (mg/L) Med.	D.O. (mg/L) Min.	D.O. (mg/L) Med.	pH (S.U.) Min.	pH (S.U.) Med.	Salinity (o/oo) Med.	Temp. (°C) Med.	Comments
1	A[6]	05/02/77	100	5	-17	1037	-.7	2.0	.3	--[3]	--	28[4]	--	5.8[4]	--	7.4[4]	--	21.0	11.6	
			100	5	-12			--	--	--	--	--	--	--	--	--	--	--	--	
			100	5	-7			--	--	--	--	--	--	--	--	--	--	--	--	
			100	5	+18			1.8	.3	--	--	28[4]	--	5.0[4]	--	7.4[4]	--	21.0	11.9	
			100	5	+33			--	--	--	--	--	--	--	--	--	--	--	--	
			100	8	+46			1.5	2.6	--	--	20[4]	--	4.1[4]	--	7.4[4]	--	20.6	11.8	
			100	4	+58			2.4	.4	--	--	--	--	5.0[4]	--	7.4[4]	--	20.6	11.8	
			100	6	+74			--	--	--	--	32[4]	--	8.1[4]	--	7.4[4]	--	20.8	11.8	
			0	40	+123			0.3	<.1	--	--	28[4]	--	7.1[4]	--	7.7[4]	--	20.4	11.6	
Median Value[5] (n = 9)			100	5	--			1.7	.3	--	--	32	28	4.1	5.1	7.4	7.4	20.7	11.8	
1	B	05/02/77	10	179	+142			--	--	--	--	--	--	--	--	--	--	--	--	
	C		0	180	+143			--	--	--	--	--	--	--	--	--	--	--	--	Strong H_2S odor at start of test
	D		0	178	+141			--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 0%
	E		0	176	+139			--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 0%
1	A	05/31/77	100	15	-13	1013	-2.1	7.0	3.5	--	--	32	30	1.6	1.9	6.5	6.7	27.2	11.9	
	B		100	170	+97			--	--	--	--	--	--	--	--	--	--	--	--	
	C		100	1	-63			--	--	--	--	--	--	--	--	--	--	--	--	
	D		0	175	+102			--	--	--	--	--	--	--	--	--	--	--	--	
	E		0	170	+97			--	--	--	--	--	--	--	--	--	--	--	--	
1	A	04/25/78	20	165	+38	1207	-1.8	--	--	--	--	--	--	--	--	--	--	--	--	
	B		10	210	+83			--	--	2.1	1.4	14	11.5	11.6	11.3	8.2	7.8	21.8	10.8	
	C		100	167	+40			--	--	--	--	--	--	--	--	--	--	--	--	
	D		0	210	+83			--	--	--	--	--	--	--	--	--	--	--	--	
	E		0	210	+83			--	--	--	--	--	--	--	--	--	--	--	--	

[1] Ten salmon per sample.

[2] Time before (-) or after (+) low tide when the last observation of the first set of test organisms was made.

[3] -- = No data.

[4] Not a median - single sample only.

[5] Median value for Area #1, A, 05/02/77 only.

[6] Repeated tests were conducted for the duration of the episode.

Table 5. - Continued.

Area	Station	Date	% Mortality[1]	Exposure Time (minutes)	LT ± T (minutes)	Low Tide Time	Low Tide Feet	Diss. Sulfides (S^{-2}) (mg/L)	H_2S Determined from S^{-2} (mg/L)	T. Sulfide (mg/L) Max.	T. Sulfide (mg/L) Med.	PBI (mg/L) Min.	PBI (mg/L) Med.	D.O. (mg/L) Min.	D.O. (mg/L) Med.	pH (S.U.) Min.	pH (S.U.) Med.	Salinity (0/00) Med.	Temp. (°C) Med.	Comments
1	A	05/08/78	100	86	+33	1207	-1.8	--[3]	--	11.0[4]	--	27[4]	--	0.0[4]	--	7.0[4]	--	25.1	13.1	
	B		100	45	-8			--	--	2.2[4]	--	23[4]	--	6.6[4]	--	7.2[4]	--	25.8	13.0	
	C		100	15	-38			--	--	4.1[4]	--	23[4]	--	0.0[4]	--	7.0[4]	--	25.4	13.2	
	D		10	125	+72			--	--	0.6[4]	--	0[4]	--	8.8[4]	--	7.0[4]	--	26.2	12.9	
	E		100	90	+37			--	--	4.0[4]	--	--	--	--	--	7.0[4]	--	25.0	13.4	
1	A	06/06/78	0	125	+36	1159	-1.3	--	--	--	--	--	--	--	--	--	--	--	--	
	B		0	125	+36			--	--	--	--	--	--	--	--	--	--	--	--	
	C		0	125	+36			--	--	--	--	23	18.5	7.6	8.6	8.0	8.1	17.3	18.3	
	D		0	125	+36			--	--	--	--	--	--	--	--	--	--	--	--	
	E		0	125	+36			--	--	--	--	--	--	--	--	--	--	--	--	
	F		0	125	+36			--	--	--	--	--	--	--	--	--	--	--	--	
1	A	06/30/81	100	100	+83	1017	-2.8	<.1	<.1	--	--	32	9	6.7	9.1	7.2	7.3	16.3	15.7	
1	A	07/01/81	100	1397	+43	1104	-3.3	.1	<.1	--	--	--	9	4.2[4]	--	7.2[4]	--	16.2	15.1	

[1] Ten salmon per sample.

[2] Time before (-) or after (+) low tide when the last observation of the first set of test organisms was made.

[3] -- = No data.

[4] Not a median - single sample only.

Table 6. Livebox bioassay and water quality data for ECOBAM study, 1974-1981, Area #2 (south end of original Weyerhaeuser pier prior to construction of the new paper loading facility).

Area	Station	Date	% Mortality[1]	Exposure Time (minutes)	LT ± T (minutes)	Low Tide Time	Low Tide Feet	Diss. Sulfides (S^{-2}) (mg/L)	H_2S Determined from S^{-2} (mg/L)	T. Sulfide (mg/L) Max.	T. Sulfide (mg/L) Med.	PBI (mg/L) Min.	PBI (mg/L) Med.	D.O. (mg/L) Min.	D.O. (mg/L) Med.	pH (S.U.) Min.	pH (S.U.) Med.	Salinity (0/00) Med.	Temp. (°C) Med.	Comments
2	A	05/02/74	0	120	+580	0750	1.9	--[3]	--	0	0	255	48	7.3	7.8	--	--	15	11.4	High tide study (1414 - 9.1')
	B		0	120	+580			--	--	--	--	--	--	--	--	--	--	--	--	
	C		0	120	+580			--	--	--	--	--	--	--	--	--	--	--	--	
	D		0	120	+580			--	--	--	--	--	--	--	--	--	--	--	--	
	E		0	120	+580			--	--	--	--	--	--	--	--	--	--	--	--	
2	A	05/09/74	100	263	+87	1226	-1.2	--	--	0	0	400[4]	--	10.8[4]	--	--	--	17	11.2	
	B		100	237	+61			--	--	--	--	--	--	--	--	--	--	--	--	
	C		0	275	+99			--	--	0	0	900	71	8.1	10.6	--	--	14.5	11.1	
	D		100	270	+94			--	--	--	--	--	--	--	--	--	--	--	--	
	E		--	--	--			--	--	--	--	--	--	--	--	--	--	--	--	Lost fish
2	A	04/29/75	0	30	+27	1403	-1.4	--	--	0	0	750[4]	--	8.0[4]	--	6.8[4]	--	29.1	9.0	24-hr. mort. 100%
	B		0	30	+27			--	--	0	0	86[4]	--	8.4[4]	--	6.8[4]	--	29.1	9.0	24-hr. mort. 10%
																6.2[4]	--			48-hr. mort. 100%
	C		0	30	+27			--	--	0	0	355[4]	--	8.3[4]	--	6.6[4]	--	29.2	9.0	24-hr. mort. 100%
																6.8[4]				48-hr. mort. 20%
	D		0	30	+27			--	--	0	0	155[4]	--	7.9[4]	--	6.6[4]	--	29.2	9.0	24-hr. mort. 10%
																6.0[4]				48-hr. mort. 10%
2	A	05/13/76	0	91	+13	1103	-2.4	--	--	--	--	--	--	10.7	10.9	7.5	7.8	--	11.8	
	B		0	89	+9			--	--	--	--	--	--	10.9	11.1	7.6	7.9	--	11.8	
	C		0	85	+2			--	--	--	--	--	--	10.9	11.2	7.7	7.9	--	12.0	
	D		0	93	+0			--	--	--	--	--	--	10.7	11.4	7.7	7.8	--	12.0	
2	A	06/09/76	20	255	+129	0921	-1.4	--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 100%
2	A	06/30/81	0	232	+262	1018	-2.8	--	--	0	0	23	5	9.2	9.6	7.8	8.0	16.9	15.9	24-hr. mort. 0%

[1] Ten salmon per sample.

[2] Time before (-) or after (+) low tide when the last observation of the first set of test organisms was made.

[3] -- = No data.

[4] Not a median - single sample only.

Table 7. Livebox bioassay and water quality data for ECCBAM study, 1974-1981, Area #3 (small embayment located between Scott Paper Company's original facilities and the tissue plant [outfall 004]).

Area	Station	Date	% Mortality[1]	Exposure Time (minutes)	LT ± T (minutes)	Low Tide Time	Low Tide Feet	Diss. Sulfides (S^{-2}) (mg/L)	H_2S Determined from S^{-2} (mg/L)	T. Sulfide (mg/L) Max.	T. Sulfide (mg/L) Med.	PBI (mg/L) Min.	PBI (mg/L) Med.	D.O. (mg/L) Min.	D.O. (mg/L) Med.	pH (S.U.) Min.	pH (S.U.) Med.	Salinity (0/00) Med.	Temp. (°C) Med.	Comments
3	A	05/16/74	0	320	+527	0703	3.2	--[3]	--	0	0	50[4]	--	--	--	7.2[4]	--	16	13.1	
	B		0	320	+527			--	--	0	0	90[4]	--	--	--	7.8[4]	--	16	12.8	
	C		0	320	+527			--	--	0	0	95[4]	--	8.9[4]	--	8.0[4]	--	15	14.7	
	D		0	320	+527			--	--	0	0	65[4]	--	8.2[4]	--	8.5[4]	--	13	17.0	
	E		0	320	+527			--	--	0	0	--	--	8.2[4]	--	6.4[4]	--	31	21.6	
3	A	05/22/74	0	280	+233	1047	-2.9	--	--	0	0	95	90	8.0	9.5	6.7	6.9	15	13.4	24-hr. mort. 0%
	B		0	285	+238			--	--	0	0	90	84	8.9	9.5	6.8	7.1	15.5	13.7	24-hr. mort. 0%
	C		10	265	+218			--	--	3.0	0	83	70	7.8	9.2	6.7	6.8	16	13.5	24-hr. mort. 10%
	D		0	275	+223			--	--	0	0	75	70	8.9	9.0	6.9	7.0	15.5	13.8	24-hr. mort. 0%
	E		20	295	+248			--	--	0.6	0	70	62	9.2	9.6	6.6	6.6	15	12.8	24-hr. mort. 100%
3	A	06/06/74	0	165	+147	1018	0.3	--	--	--	--	40	40	9.4	9.7	7.4	7.5	13	11.3	24-hr. mort. 0%
	B		0	150	+137			--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 0%
	C		0	150	+132			--	--	C	0	40	40	9.5	9.7	7.5	7.5	13	11.2	24-hr. mort. 0%
	D		0	180	+162			--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 0%
	E		0	185	+167			--	--	--	--	40	3.7	9.1	9.6	7.6	7.6	13.5	11.5	24-hr. mort. 0%
3	A	06/11/75	0	120	+87	1233	-2.7	--	--	0.2	0.2	41	36	7.8	8.7	7.6	7.6	13.0	16.3	24-hr. mort. 0%
	B		0	120	+87			--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 0%
	C		0	120	+87			--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 0%
	D		0	120	+87			--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 0%
	E		0	120	+87			--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 0%
3	A	06/09/76	0	120	+76	0912	-1.4	0.0	0.0	--	--	--	--	--	--	--	--	--	14.6	
	B		0	--	--			--	--	--	--	--	--	--	--	--	--	--	--	
	C		0	120	+71			<.1	--	--	--	--	--	--	--	--	--	--	14.5	
	D		0	73	+1			<.1	--	--	--	--	--	--	--	--	--	--	17.4	
	E		0	123	+66			0.0	0.0	--	--	--	--	--	--	--	--	--	15.4	
3	A	05/03/77	0	215	+35	1120	-1.8	--	--	--	--	--	--	--	--	--	--	--	--	
	B		0	195	+30			--	--	--	--	--	--	--	--	--	--	--	--	
	C		0	203	+33			--	--	--	--	--	--	--	--	--	--	--	--	
	D		0	175	+30			--	--	--	--	--	--	--	--	--	--	--	--	
	E		0	160	+35			--	--	--	--	4[illegible]	36	6.6	7.0	7.2	7.3	26.1	11.1	24-hr. mort. 0%
3	A	04/24/78	0	130	-12	1212	-1.1	--	--	--	--	--	--	--	--	--	--	--	--	
	B		0	130	-12			--	--	--	--	--	--	--	--	--	--	--	--	
	C		0	130	-12			--	--	--	--	--	--	--	--	--	--	--	--	
	D		0	130	-12			--	--	--	--	--	--	--	--	--	--	--	--	
	E		0	155	-12			--	--	0	0	18	18	9.3	9.6	7.1	7.7	24.3	11.0	

[1] Ten salmon per sample.

[2] Time before (-) or after (+) low tide when the last observation of the first set of test organisms was made.

[3] -- = No data.

Table 8. Livebox bioassay and water quality data for ECOBAM study, 1974-1981, Area #4 (south end of Scott pier anc adjacent to the pier and the main diffuser [outfa'l 003]).

Area	Station	Date	% Mortality[1]	Exposure Time (minutes)	LT ± T (minutes)	Low Tide Time	Low Tide Feet	Diss. Sulfides (S^{-2}) (mg/L)	H_2S Determined from S^{-2} (mg/L)	T. Sulfide (mg/L) Max.	T. Sulfide (mg/L) Med.	PBI (mg/L) Min.	PBI (mg/L) Med.	D.O. (mg/L) Min.	D.O. (mg/L) Med.	pH (S.U.) Min.	pH (S.U.) Med.	Salinity (0/00) Med.	Temp. (°C) Med.	Comments
4	A	06/04/74	100	45	+12	1013	-1.9	--[3]	--	0	0	225	162.5	9.0	9.0	6.4	6.6	25.0	10.7	
	B		0	272	+225			--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 10%
	C		0	274	+227			--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 10%
	D		0	276	+229			--	--	0	0	133	108	5.7	6.2	7.0	7.1	24.0	11.1	24-hr. mort. 20%
	E		0	278	+231			--	--	0	0	100	93	5.3	5.4	6.6	6.9	22	10.9	24-hr. mort. 0%
4	A	05/14/75	0	150	+14	1334	-1.8	--	--	0	0	--	--	9.6	10.4	7.2	7.2	19.6	14.0	24-hr. mort. N/A
	B		0	148	+134			--	--	0	0	--	--	10.4	10.4	7.1	7.2	19.3	13.6	24-hr. mort. 10%
	C		10	92	+88			--	--	0	0	--	--	10.2	10.4	7.0	7.3	19.4	13.6	24-hr. mort. 0%
	D		0	138	+144			--	--	0	0	--	--	10.2	10.4	7.2	7.2	19.7	13.8	24-hr. mort. N/A
	E		0	162	+108			--	--	0	0	--	--	8.6	10.3	7.0	7.2	20.8	13.9	24-hr. mort. 0%
4	A	05/12/76	0	50	-44	1019	-1.5	--	--	0	0	--	--	11.9[4]	--	8.0[4]	--	--	16.5	
4	A	05/13/76	0	140	+7	1103	-2.4	--	--	0	0	--	--	10.6	11.0	8.1	8.1	14.8	11.4	24-hr. mort. 0%
	B		0	130	+12			--	--	0	0	--	--	10.5	10.8	8.1	8.2	16.0	10.9	24-hr. mort. 10%
	C		0	120	-3			--	--	0	0	14[4]	--	10.7	10.8	8.0	8.1	14.7	10.9	24-hr. mort. 0%
	D		0	130	+17			--	--	0	0	--	--	10.8	10.9	8.2	8.3	15.0	11.0	
4	A	05/24/77	0	65	-79	1542	.9	--	--	--	--	--	--	--	--	--	--	--	--	24-hr. mort. 0%
	B		0	64	-80			--	--	--	--	--	--	--	--	--	--	--	--	
	C		100	63	-81			--	--	--	--	--	--	--	--	--	--	--	--	Free Cl_2 .5 mg/L
4	A	06/01/77	0	225	+96	1109	-2.8	--	--	--	--	--	--	--	--	--	--	--	--	
	C		100	210	+81			--	--	0	0	110	56.5	8.1	9.0	6.4	6.7	25.3	11.8	Free Cl_2 Max. 0.3; Med. 0.0
4	A	04/26/78	10	178	+53	1255	-1.8	--	--	0	0	9[4]	--	11.2[4]	--	7.9[4]	--	23.8	10.8	Free Cl_2 was not detectable
	B		90	175	+50			--	--	0	0	36	36	11.0[4]	--	6.7[4]	--	23.2	10.5	
	C		50	170	+45			--	--	0	0	--	--	11.3[4]	--	7.9[4]	--	24.9	10.5	
	D		0	180	+55			--	--	0	0	--	--	--	--	--	--	--	--	
4	A	05/09/78	0	240	+121	1259	-0.8	--	--	0	0	32[4]	--	9.2[4]	--	7.5[4]	--	24.3	12.7	
	B		0	240	+121			--	--	0	0	27[4]	--	10.4[4]	--	8.0[4]	--	23.5	12.7	
	C		0	245	+126			--	--	0	0	104[4]	--	7.4[4]	--	8.0[4]	--	24.3	12.6	
4	A	06/05/78	0	155	+270	1125	-1.2	--	--	--	--	8[4]	--	10.5[4]	--	8.0[4]	--	16.4	18.8	24-hr. mort. 0%
	C		0	150	+265			--	--	--	--	9[4]	--	9.9[4]	--	8.0[4]	--	16.9	19.9	24-hr. mort. 10%
	D		0	170	+285			--	--	--	--	9[4]	--	11.4[4]	--	8.0[4]	--	16.7	19.6	24-hr. mort. 0%
4	C	06/30/81	30	285	+233	1017	-2.8	<.1	<.1	--	--	350	270	3.6	7.3	7.3	7.4	17.7	15.8	

[1] Ten salmon per sample.

[2] Time before (-) or after (+) low tide when the last observation of the first set of test organisms was made.

Table 9. Livebox bioassay and water quality data for ECOBAM study, 1974-1981, Area #5 (northeast terminus of the east waterway [outfall 008]) and Area #6 (south end of the Snohomish River/east waterway jetty).

Area	Station	Date	% Mortality[1]	Exposure Time (minutes)	LT ± T (minutes)	Low Tide Time	Low Tide Feet	Diss. Sulfides (S^{-2}) (mg/L)	H_2S Determined from S^{-2} (mg/L)	T. Sulfide (mg/L) Max.	T. Sulfide (mg/L) Med.	PBI (mg/L) Min.	PBI (mg/L) Med.	D.O. (mg/L) Min.	D.O. (mg/L) Med.	pH (S.U.) Min.	pH (S.U.) Med.	Salinity (O/OO) Med.	Temp. (°C) Med.	Comments
5	A	06/30/81	0	120	117	1018	-2.8	<.1	<.1	--[3]	--	9	7	6.0	8.3	7.2	7.4	17.0	16.6	24-hr. mort. 0%
6	A	06/30/81	0	326	378	1018	-2.8	0.0	0.0	--	--	5	2.5	9.0	9.5	7.7	7.9	16.8	16.2	24-hr. mort. 0%

[1] Ten salmon per sample.

[2] Time before (-) or after (+) low tide when the last observation of the first set of test organisms was made.

[3] -- = No data.

Table 10. Scott[1/] bioassay summary; percent survival in 65 percent effluent for 96-hour test period.

		Outfalls				
Date	Control	001 Deepwater Diffuser	003 Main Diffuser	004[2/] Bleach Plant	008 Treatment Plant	Benson
01/29/80		100	21	100	94	
02/09/80		--	70	--	--	
02/26/80		90	95	100	55	
03/11/80		100	100	90	53	
04/22/80		90	63	70	60	
05/06/80		78	48	98	55	
06/24/80		95	13	95	100	
07/29/80		98	90	98	95	
08/24/80		100	100	93	90	100
09/21/80		93	98	83	78	93
10/26/80		100	93	100	100	93
11/07/80		95	88	100	80	95
12/07/80		95	35		100	95
01/25/81		0	8		93	0
02/24/81		0	0		83	0
03/10/81		100	0		67	5
03/14/81		95	50			
04/12/81	98	80	30		88	23
04/21/81	90		85			90
05/03/81	95		93			93
05/25/81	88	60	0		45	93
06/14/81	88	83	20		70	80
07/15/81	98	85	5		10	95
08/05/81	100	63	38		48	53

[1/] Table derived from data obtained from Scott Paper Company.

[2/] 004 outfall discontinued April 1981. Effluent now combined with outfalls 001 and 003.

Table 15. Comparison of phthalate ester concentrations in fish from Everett Harbor and Port Gardner with fish from other areas of Washington State.

	Everett (muscle tissue analysis)		10EPATOX Samples (whole fish analysis)	
	$\bar{X}$	Range	$\bar{X}$	Range
DEHP*	0.05	(0.005-0.17)	0.41	(0.01-1.5)
butyl-benzyl	0.011		0.13	(0.01-0.3)
di-n-butyl	0.72	(0.06-0.8)	0.87	(0.03-2.3)
diethyl	0.01	(0.007-0.92)	0.50	(0.03-1.4)
dimethyl	0.002		0.51	

Notes:

*bis(2-ethylhexyl) phalate

Source: Anon, EPA, 1981.

Concentrations are in μg/g (ppm), wet weight.